RE SOURCES

Stormwater Outfall Monitoring Program

Three-year summary | March 2024

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Summary

In February 2021, RE Sources began a stormwater monitoring program that analyzes stormwater outfalls and urban creek outlets that flow directly into Bellingham Bay. The program began with 8 monitoring stations and now in 2023, 6 outfalls and 4 urban creeks are analyzed for a total of 10 monitoring stations. Willow outfall had been added to the program in 2022 but was dropped in 2023 because it had very few exceedances during the 2022 sampling year and does not appear to be a pollution concern. When arriving at a sampling site, the water is initially assessed for: visuals (such as sheens or foam), odor, color, and flow. Then, basic water quality parameters are measured including dissolved oxygen (mg/l), water temperature (°C), conductivity (µS/cm), pH, turbidity (cm/NTU), and *Escherichia coli* (*E. coli*) and *Enterococcus* bacteria (CFU/100ml).

During the 2023 sampling year, a few important changes were made to this monitoring program. In September, *Enterococcus*, the indicator bacteria species for marine waters, was added to the bacteria sampling. Many of the outfalls and creeks experience marine intrusion on a regular basis and, therefore, *Enterococcus* may play an important role in understanding fecal coliform contamination. In July, we began using an AMTAST turbidity meter that measures how much light is scattered by particles in a water sample instead of a turbidity tube that is based on what height a person can see a secchi disc at the bottom of a plastic tube. In September, Verify chemical test strips were included in the sampling protocol and measure: pH, hardness (ppm), hydrogen sulfide (ppm), iron (ppm), copper (ppm), lead (ppb), manganese (ppm), total chlorine (ppm), mercury (ppm), nitrate (ppm), nitrate (ppm), sulfate (ppm), zinc (ppm), fluoride (ppm), sodium chloride (ppm), total alkalinity (ppm).

Perhaps most importantly, the Bellingham Bay Stormwater Monitoring program joined forces with 6 other programs to form the Salish Sea Stormwater Monitoring Program. The 6 other programs are located in: Anacortes, Oak Harbor, Everett, Mukilteo, Edmonds, and Shoreline (with the potential to expand into other regions). Procedures and methods were harmonized between the 7 programs and now all the data is stored in a collective database.

In the process of collaborating with the other programs, RE Sources also converted this program into a community science endeavor. About 20 volunteers have been trained and are now monitoring the outfalls and creeks. RE Sources continues to manage the Bellingham program.

In addition to the routine stormwater sampling, RE Sources also conducted PFAS (per- and polyfluoroalkyl substances, a.k.a. “forever chemicals”) sampling after the first significant fall rain. All routine monitoring sites were sampled, plus one additional sample on Squalicum Creek. Cyclopure PFAS sampling kits and lab were used for analysis.

Similar to 2021 and 2022, all of the outfalls and creeks failed to meet water quality standards at least once during the 2023 sampling period, but there was great variability between the monitoring sites. Color had the most exceedances of all the parameters and many of these observances could be explained by natural causes such as tannins. Water temperature, visual, *E. coli* and *Enterococcus* parameters were the next highest exceedances.

Four outfalls and 2 creeks were rated as **“Threat”** because they frequently violated water quality standards and/or had a high likelihood of human exposure. The 6th outfall and other 2 creeks were rated as **“Watch”** because they had a moderate number of exceedances, some of which could have been due to natural causes. The one outfall that was rated as **“Good”** in 2022 was eliminated from the sampling program in 2023 because it did not appear to be a source of pollution. Therefore, in 2023, none of the creeks or outfalls were rated **“Good”**.

Purpose

Stormwater is the single largest source of pollution to the Salish Sea and is one of the biggest threats to this ecosystem — yet it is one of the most challenging forms of pollution to prevent (Ecology and King County, 2011). It is also harmful to people, particularly Subsistence communities, including the Coast Salish, who consume larger quantities of food from the Salish Sea than other groups. Monitoring large stormwater outfalls that dump into Bellingham Bay on a regular basis helps to pinpoint illicit discharges and other sources of pollution with the intent to find the source of pollution and fix it. The outfalls and creeks monitored here drain the majority of the built-out area of downtown Bellingham and includes residential housing, businesses, industry, and public parks and trails. The outfalls themselves drain a total of approximately 140,000 linear feet of pipe.

Stormwater permit holders such as the City of Bellingham (COB) and the Port of Bellingham (POB) have minimal monitoring requirements and are faced with staff and resource shortages, leaving them unable to adequately monitor all of the outfalls in Bellingham (Ecology, 2019). Local and state stormwater managers were consulted during the early stages of this project and have been kept informed throughout. This project is helping to inform stormwater managers about the quality of the stormwater entering the Bay and hopefully help focus efforts on problem spots. Recently, one of our monitoring sites has been chosen to be monitored by the Department of Ecology and Health Department to assess the safety of saltwater swimming beaches. Hopefully, more examples of this type of work will manifest over the next couple of years.

Methods

The 6 outfalls and 4 creeks that are monitored all discharge into Bellingham Bay and drain significant portions of the built-out areas of downtown Bellingham. See Appendix 1 for a map of the outfall and stream sampling locations.

***Outfall Names and Descriptions*:**

1. Broadway Street Outfall: This outfall drains much of Columbia Neighborhood — specifically the area bordered by Broadway St. to the southeast, W Illinois St. to the northwest, and Squalicum Creek to the northwest. It dumps into the I & J Waterway and is underwater during moderate to high tides. The COB describes this outfall as having 2 separate basins that join just up the pipe of where the outfall is located.
2. C Street Outfall: This outfall drains much of the industrial area in the Central Waterfront property that is on either side of C St, just southwest of Roeder Ave., along with the Lettered Street neighborhood that resides in the area that is southwest of Dupont St.
3. Cornwall Avenue Outfall: This outfall drains Cornwall Ave. up to Laurel St.
4. Cedar Street Outfall: This outfall drains the hillside that originates up at Western Washington University.
5. Olive Outfall (formerly called Boulevard): This outfall drains the hillside that is directly above and north of Boulevard Park.
6. Bennett Street Outfall: This outfall drains the hillside that is directly above and south of Boulevard Park, visible from the Taylor St. dock and boardwalk.
7. Willow Street Outfall (added 2022; removed 2023): This outfall drains the southern part of Edgemoor neighborhood. It is mentioned here for information only and is not discussed further in this document.

Table 1. Peak simulated flow from each basin (City of Bellingham, 2020).

Basin Name	2-year Event			10-year Event			25-year Event			100-year Event		
	Existing Conditions Runoff (cfs)	Full Build-Out Runoff (cfs)	Change	Existing Conditions Runoff (cfs)	Full Build-Out Runoff (cfs)	Change	Existing Conditions Runoff (cfs)	Full Build-Out Runoff (cfs)	Change	Existing Conditions Runoff (cfs)	Full Build-Out Runoff (cfs)	Change
Arbutus	5	7	+2	9	13	+4	11	16	+5	16	21	+5
Bennett	9	14	+5	15	23	+8	19	27	+8	24	34	+10
Broadway	45	65	+20	82	109	+27	103	132	+29	136	169	+33
Cedar	11	14	+3	18	23	+5	21	28	+7	26	35	+9
C St.	21	26	+5	35	42	+7	42	50	+8	53	63	+10
Ellsworth	14	16	+2	25	27	+2	32	34	+2	41	43	+2
Laurel	18	26	+8	30	42	+12	35	50	+15	44	63	+19
Olive	10	16	+6	18	26	+8	22	32	+10	30	40	+10
Willow	8	12	+4	14	20	+6	17	24	+7	23	30	+7

Table 2. Effective impervious areas by basin for existing and full build-out land-use scenarios (City of Bellingham, 2020).

Basin Name	Area (AC)	Existing Conditions Percent Effective Impervious	Full Build-Out Percent Effective Impervious	Change from Existing
Arbutus	52.3	15%	28%	+13%
Bennett	92.4	23%	36%	+13%
Broadway	393.7	24%	39%	+15%
Cedar	93.5	28%	35%	+7%
C St.	87.7	62%	79%	+17%
Ellsworth	93.5	33%	38%	+5%
Laurel	97.9	48%	67%	+19%
Olive	125.0	18%	29%	+11%
Willow	97.7	18%	28%	+10%

Creek Names and Descriptions:

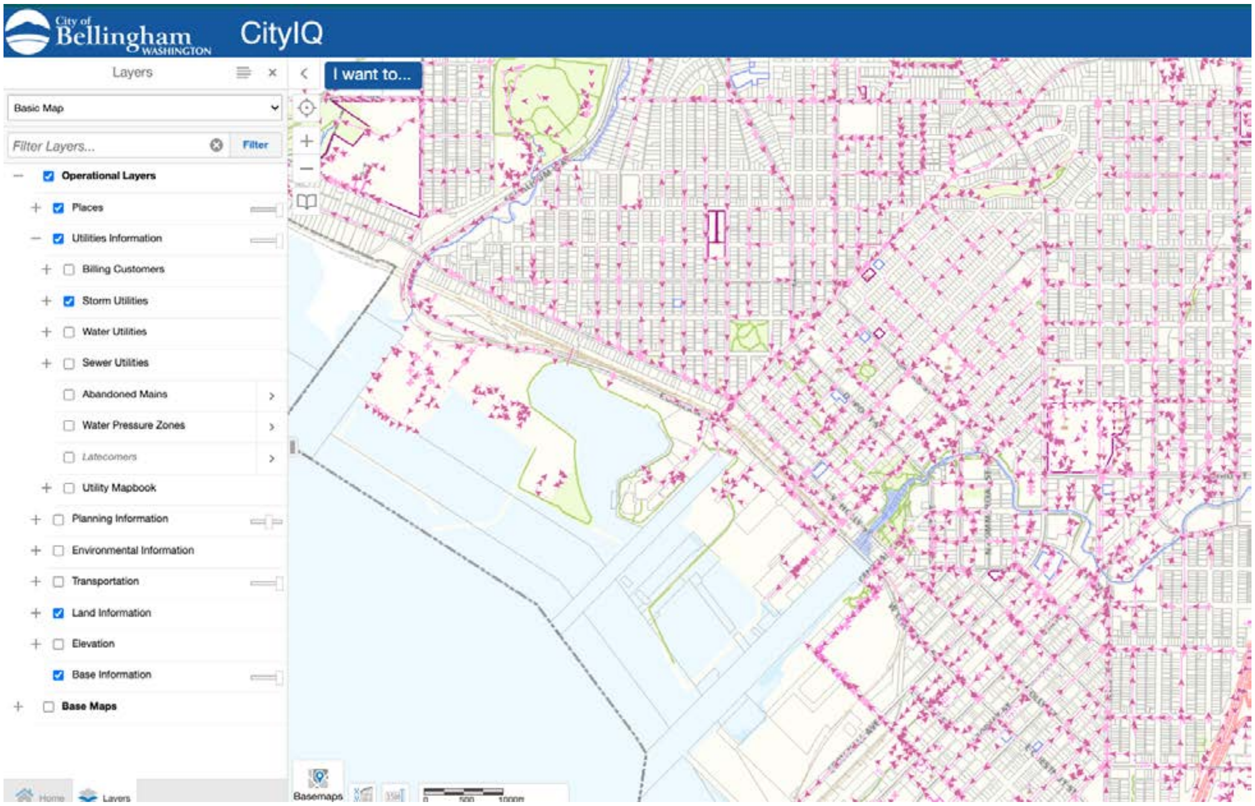
1. **Little Squalicum Creek** (added 2022): This creek is fed by springs and seeps located in Little Squalicum Park and stormwater runoff from Birchwood and Cedarwood neighborhoods as well as Bellingham Technical College and Oeser Company. The 36-inch culvert at the shoreline that was considered a fish passage barrier was removed in 2023 and a large estuary restoration project was completed where the creek discharges into Bellingham Bay. Because of this construction, this creek was not sampled between Nov 2022 and Feb 2023. After restoration was completed, the monitoring location was moved upstream from the new estuary. Little Squalicum

Creek is considered an impaired creek because it does not regularly meet the water quality standards for copper.

2. **Squalicum Creek:** Squalicum Lake is the headwaters to this urban creek and is located near the intersection of SR 542 and the Y road. It drains approximately 22 square miles and flows through agricultural land, residential, commercial, and industrial areas. Squalicum Way, a popular truck route, is near the outlet, which has considerable stormwater input. Much of the creek's watershed is developed and impervious. Its water levels rise and fall dramatically following rain events. Furthermore, it suffers from low flow events during the summer because it does not have snow melt to feed it. Squalicum Creek is considered an impaired creek because it does not regularly meet the water quality standards for fecal coliform, dissolved oxygen, and temperature. Pink, chum, and coho salmon as well as cutthroat trout use the stream. Steelhead trout, Chinook, and sockeye have also been documented in the stream on occasion.
3. **Whatcom Creek:** Lake Whatcom is the headwaters to this creek and the flow is controlled by a dam. The creek flows through built-out areas and heavily used areas such as public parks, industrial areas, along with residential and commercial areas. Whatcom Creek is considered an impaired creek because it does not regularly meet the water quality standards for fecal coliform, dissolved oxygen, and temperature. Coho, chum, and Chinook salmon as well as steelhead and resident sea-run cutthroat trout inhabit the stream.
4. **Padden Creek** (added 2022): The Padden Creek watershed consists of an area measuring 4,125 acres and has headwaters in the Chuckanut Mountains and South Samish Crest. It drains Lake Padden and approximately 6 square miles of South Bellingham. Connolly Creek is a major tributary. Padden Creek is considered an impaired creek because it does not regularly meet the water quality standards for fecal coliform, dissolved oxygen, and temperature. Chum and coho use this stream. Chinook, Steelhead, and sea-run cutthroat trout have also been documented in the creek.

For a more detailed look at where stormwater flows in Bellingham, open the CityIQ software on the City of Bellingham's website (www.cob.org) and select Storm Utilities.

Fig 1. Screenshot of the Stormwater drainage system from CityIQ software.



The water quality standards that are used for the 4 creeks in this study are taken from Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC). The standards for the stormwater outfalls are taken from the Illicit Connection and Illicit Discharge Field Screening and Source Tracing Guidance Manual (Herrera and Aspect, 2020).

Sampling

Pilot testing began in December 2020 and monthly monitoring of all sites began in February 2021. Samples were collected by car and by kayak or canoe during times when the tides were + 2.0 or lower. Several of the outfalls are under water during higher tides. Testing done during the winter months (November, December, January, and some in February) are conducted during the evening with headlamps, as that is the only time the tide is low enough to monitor. See Appendices 2 and 3 for detailed explanations of the procedures that are used and see Appendices 4-6 for the data sheets that include the appropriate water quality standards.

PFAS sampling was done on October 25th and 26th within 24 hours of when 1.7 inches of rain fell in Bellingham. This was the first significant rain event and was considered the first fall flush event for this region. All routine monitoring sites were sampled (see Appendix 1) plus one additional site on Squalicum creek in Cornwall Park. Samples were taken and filtered in containers provided by Cyclopure and mailed to their lab for analysis. (https://cyclopure.com/).

When exceedances are found, reports are sent to the Washington State Department of Ecology (Ecology's Emergency Response Tracking System) and/or the COB Stormwater Department. This helps to find and stop the source of pollution and hold both regulators and polluters accountable.

Results

All of the data is located and displayed within the Water Reporter Map (link). Below is an overview of the results for each of the monitoring sites for 2021, 2022, and 2023. A summary table is also provided that includes an overall rating of the monitoring sites.

Note: Some data points are missing due to malfunctioning equipment such as the dissolved oxygen probe and *E. coli* R cards.

Overall Rating

Sites were assigned one of three ratings: Threat, Watch, or Good.

- Threat (red): This signifies that the site has severe exceedances for any given parameter that occur regularly (not just once or twice).
- Watch (yellow): This signifies that the site has some exceedances for any given parameter but they are either very infrequent or unable to link to a pollution source.
- Good (green): This signifies that the site rarely has an exceedance for any given parameter and when it does occur it is not egregious.

Table 3. Total number and percentage of exceedances by year with overall rating. In fall 2023, *Enterococcus* and chemical strip testing was introduced. Because these tests were not performed in 2021 or 2022, they were kept separately.

Outfall	2021	2022	2023**	2023 Entero	2023 Chem Strips	Rating
Broadway (#)	6	12	12(13)	1	2	Watch
Broadway (%)	3.7	9	8.4(9)	50	6	
C St (#)	22	40	37	3	10	Threat
C st (%)	14.6	26	24	50	14	
Cornwall (#)	11	20	11	0	9	Threat
Cornwall (%)	8.5	12.1	7.8	0	15	
Cedar (#)	4	23	16(17)	1	10	Threat
Cedar (%)	3.1	13.9	12.3 (13)	33	17	
Olive (#)	6	11	6(9)	3	4	Threat
Olive (%)	4.6	8.3	4.7 (7)	50	11	
Bennett (#)	10	20	8(9)	1	2	Threat
Bennett (%)	8.4	12.1	5.7 (6)	20	6	

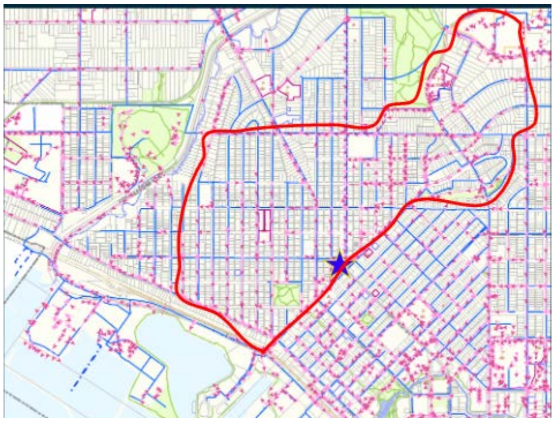
Creek	2021	2022	2023**	2023 Entero	2023 Chem Strips	Rating
Little Squalicum*(#)	NA	3	13(14)	3	2	Watch
LIttle Squalicum (%)	NA	5.6	13.3 (14)	75	8	
Squalicum (#)	19	28	27(29)	6	12	Threat
Squalicum (%)	16	21.2	17.7 (19)	100	20	
Whatcom (#)	12	11	16	2	5	Threat
Whatcom (%)	9.2	7.7	9.7	40	21	
Padden (#)	NA	9	21(24)	4	4	Watch
Padden (%)	NA	9.1	12.6 (14)	50	7	
Total (#)	85	171	156(167)	24	60	
Total (%)	7.9	12.2	10.3 (11)	47	13	

**Little Squalicum was not sampled between Nov 2022 and Feb 2023 because of an estuary restoration project and, therefore, has less data points.*

***E. Coli R cards were not functioning for 2 months. Based on Enterococcus results from the same sample, there were likely 11 exceedances that were not recognized, these values are included in the numbers in the parentheses.*

Outfalls:

1. **Broadway Street Outfall:**

Photo of Outfall:	Approximate drainage area:
	

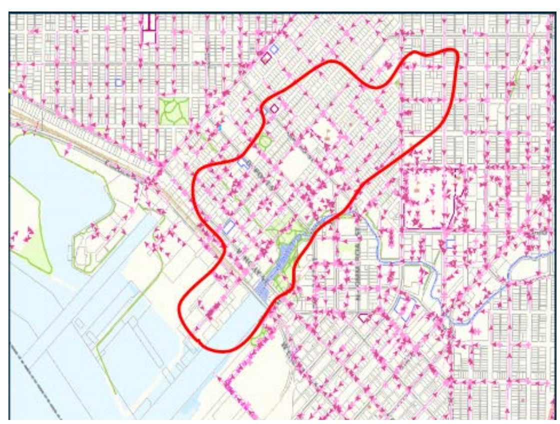
Number of Exceedances and Percentage of Exceedances at Broadway Outfall						
Parameter	2021		2022		2023*	
	#	%	#	%	#	%
Water Temp ^{0}C	1	7	4	33	1	8
E. coli cfu/100ml	1	7	3	25	0(1)	0(8)
Entero cfu/100ml	-	-	-	-	1	50
Color	2	13	3	25	7	54
Odor	2	13	0	0	2	15
Visual	0	0	2	16	2	15
Total Chlorine ppm	-	-	-	-	1	33
Nitrite ppm	-	-	-	-	1	33

PFAS Compound	Amount detected ppt
PFPeA	1.2
PFHxA	1.1
PFOA	1.4
PFBS	1.5
PFOS	3.4
Total	**8.6**

Rating: Watch

**E. Coli R cards were not functioning for 2 months. Based on Enterococcus results from the same sample, there was likely 1 exceedance that was not recognized, this value is included in the numbers in the parentheses.*

2. C Street Outfall:

Photo of Outfall:	Approximate drainage area:
	

Number of Exceedances and Percentage of Exceedances at C St Outfall						
Parameter	**2021**		**2022**		**2023**	
	#	**%**	**#**	**%**	**#**	**%**
Water Temp ^{0}C	1	7	4	29	3	21
Dissolved Oxygen mg/L	4	36	2	14	0	0
E. coli cfu/100ml	1	7	8	57	4	36
Entero cfu/100ml	-	-	-	-	3	50
Color	6	43	6	43	9	64
Odor	4	29	7	50	9	64
Visual	6	43	13	93	12	86
Lead ppb	-	-	-	-	1	17
Nitrate ppm	-	-	-	-	2	33
Nitrite ppm	-	-	-	-	2	33
Sulfate ppm	-	-	-	-	2	33
Zinc ppm	-	-	-	-	1	17
Fluoride ppm	-	-	-	-	2	33

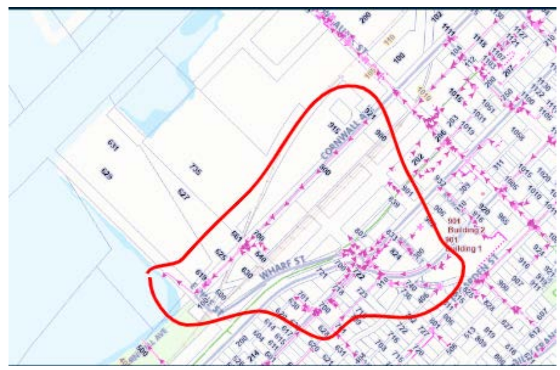
PFAS Compound	Amount detected ppt
PFPeA	1.2
PFHxA	1.9
PFHpA	1.3
PFOA	4.2
PFBS	3.1
PFHxS	1

PFOS	9.2
Total	**21.9**

Rating: Threat

3. Cornwall Avenue Outfall:

Photo of Outfall:	Approximate drainage area:



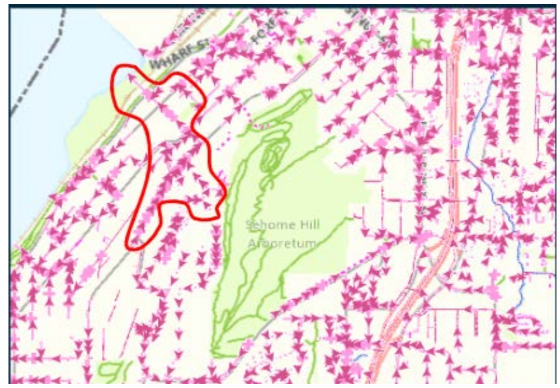
Number of Exceedances and Percentage of Exceedances at Cornwall Ave Outfall						
Parameter	**2021**		**2022**		**2023**	
	#	**%**	**#**	**%**	**#**	**%**
Water Temp ^{0}C	2	17	7	47	4	31
Dissolved Oxygen mg/L	7	70	8	53	5	50
E. coli cfu/100ml	1	8	4	27	0	0
Entero cfu/100ml	-	-	-	-	0	0
Color	1	8	1	7	2	15
Odor	0	0	0	0	0	0

Visual	0	0	0	0	0	0
Mercury ppm	-	-	-	-	3	60
Sulfate ppm	-	-	-	-	1	20
Zinc ppm	-	-	-	-	3	60
Fluoride ppm	-	-	-	-	2	40

PFAS Compound	Amount detected ppt
PFPeA	2.6
PFHxA	2.2
PFHpA	1.8
PFOA	2
PFOS	2.1
6:2 FTS	1.2
Total	**11.9 ppt**

Rating: Threat

4. Cedar Street Outfall:

Photo of Outfall:	Approximate drainage area:
	

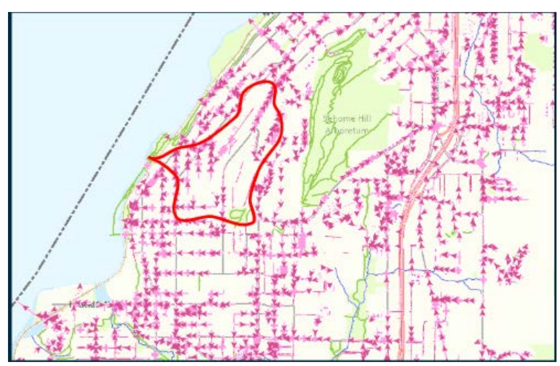
Number of Exceedances and Percentage of Exceedances at Cedar St Outfall						
Parameter	2021		2022		2023*	
	#	%	#	%	#	%
Water Temp ^{0}C	2	17	7	47	4	33
E. coli cfu/100ml	1	8	9	60	0(1)	0(10)
Entero cfu/100ml	-	-	-	-	1	33
Color	0	0	4	27	8	67
Odor	1	8	2	13	3	25
Visual	0	0	1	7	1	8
Mercury ppm	-	-	-	-	1	20
Sulfate ppm	-	-	-	-	4	80
Zinc ppm	-	-	-	-	1	20
Fluoride ppm	-	-	-	-	4	80

PFAS Compound	Amount detected ppt
PFBA	1.5
PFPeA	7.4
PFHxA	12.5
PFHpA	3.4
PFOA	8.1
PFNA	1.9
PFDA	1
PFBS	4.4
PFHxS	3.3
PFOS	9.9
Total	**53.4**

Rating: Threat

**E. Coli* R cards were not functioning for 2 months. Based on *Enterococcus* results from the same sample, there was likely 1 exceedance that was not recognized, this value is included in the numbers in the parentheses.

5. **Olive Outfall (formerly called Boulevard):**

Photo of Outfall:	**Approximate drainage area:**
	

Number of Exceedances and Percentage of Exceedances at Olive Outfall:						
Parameter	**2021**		**2022**		**2023***	
	#	**%**	**#**	**%**	**#**	**%**
Flow	0	0	1	8	0	0
Water Temp ^{0}C	1	8	4	33	4	31
Turbidity uS/cm	0	0	1	8	0	0
E. coli cfu/100ml	5	42	4	33	1(3)	10(40)
Entero cfu/100ml	-	-	-	-	3	60
Color	0	0	1	8	0	0
Odor	0	0	0	0	1	8
Visual	0	0	0	0	0	0
Mercury ppm	-	-	-	-	1	33
Sulfate ppm	-	-	-	-	3	100

PFAS Compound	Amount detected ppt
PFPeA	3.4
PFHxA	4.3
PFHpA	2.2
PFOA	7.2
PFBS	6.5
PFHxS	1.9
PFOS	8.4
Total	**33.9**

Rating: Threat

E. Coli R cards were not functioning for 2 months. Based on *Enterococcus* results from the same sample, there were likely 3 exceedances that were not recognized, this value is included in the numbers in the parentheses.

6. Bennett Street Outfall:

Photo of Outfall:	Approximate drainage area:
	

Number of Exceedances and Percentage of Exceedances at Bennett Outfall:						
Parameter	**2021**		**2022**		**2023***	
	#	**%**	**#**	**%**	**#**	**%**
Water Temp ^{0}C	1	9	7	47	4	31
E. coli cfu/100ml	8	73	11	73	4(1)	40(50)
Entero cfu/100ml	-	-	-	-	1	20
Color	1	9	0	0	0	0
Visual	0	0	2	13	0	0
Sulfate	-	-	-	-	2	67

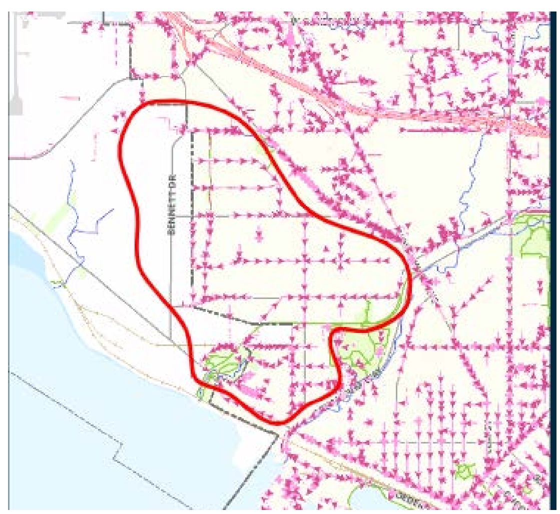
PFAS Compound	Amount detected ppt
PFPeA	4.2
PFHxA	4.5
PFHpA	2.1
PFOA	4.9
PFBS	5.2
PFHxS	1.8
PFOS	8.3
Total	**31.0**

Rating: Threat

**E. Coli* R cards were not functioning for 2 months. Based on *Enterococcus* results from the same sample, there was likely 1 exceedance that was not recognized, this value is included in the numbers in the parentheses.

Creeks:

1. **Little Squalicum Creek** (partial sampling in 2022 and 2023 because of estuary restoration project):

Photo of Creek:	**Approximate drainage area:**
	

Number of Exceedances and Percentage of Exceedances at Little Squalicum Creek						
Parameter	**2021**		**2022**		**2023***	
	#	**%**	**#**	**%**	**#**	**%**
Water Temp ^{0}C	-	-	0	0	1	11
Dissolved Oxygen mg/L	-	-	0	0	2	33
pH	-	-	1	20	0	0
Turbidity uS/cm	-	-	0	0	2	22
E. coli cfu/100ml	-	-	1	20	2(1)	25(38)
Entero cfu/100ml	-	-	-	-	3	75
Color	-	-	1	20	3	38
Visual	-	-	0	0	3	33
Sulfate ppm	-	-	-	-	1	50
Zinc ppm	-	-	-	-	1	50

PFAS Compound	Amount detected ppt
PFHxA	1
PFOA	1.7
PFOS	2.3
Total	**5.0 ppt**

Rating: Watch

**E. Coli R cards were not functioning for 2 months. Based on* Enterococcus *results from the same sample, there was likely 1 exceedance that was not recognized, this value is included in the numbers in the parentheses.*

2. Squalicum Creek:

Photo of Creek:	Approximate drainage area:
	

Number of Exceedances and Percentage of Exceedances at Squalicum Creek						
Parameter	**2021**		**2022**		**2023***	
	#	**%**	**#**	**%**	**#**	**%**
Water Temp ^{0}C	2	18	2	17	4	29
Dissolved Oxygen mg/L	3	33	2	17	2	17
pH	0	0	3	25	0	0
Turbidity uS/cm	2	18	2	17	2	14
E. coli cfu/100ml	1	9	5	42	1(2)	9(27)
Entero cfu/100ml	-	-	-	-	6	100
Color	5	45	10	83	10	83
Visual	6	54	4	33	8	57
Lead ppb	-	-	-	-	2	40

Total Chlorine ppm	-	-	-	-	2	40
Nitrate ppm	-	-	-	-	1	20
Nitrite ppm	-	-	-	-	1	20
Sulfate ppm	-	-	-	-	4	80
Zinc ppm	-	-	-	-	2	40

PFAS Compound	Amount detected ppt at Roeder	Amount detected ppt at Cornwall Park
PFPeA	1.4	1.3
PFHxA	1.5	3.2
PFHpA	< 1.0 ppt	1
PFOA	1.8	1.5
PFBS	1.7	1.6
PFHxS	< 1.0 ppt	3.7
PFOS	2.4	6.5
3:3 FTCA	4	< 1.0 ppt
Total	**12.8**	**18.8**

Rating: Threat

*E. Coli R *cards were not functioning for 2 months. Based on* Enterococcus *results from the same sample, there were likely 2 exceedances that were not recognized, this value is included in the numbers in the parentheses.*

3. Whatcom Creek:

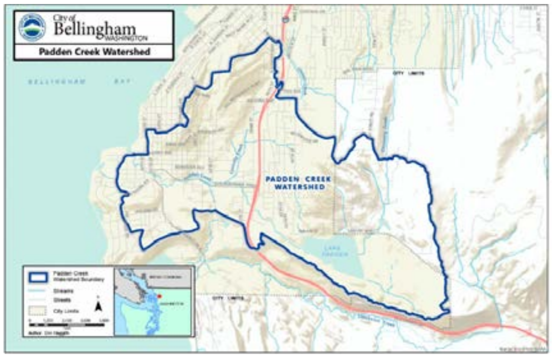
Photo of Creek:	Approximate drainage area:
	

Number of Exceedances and Percentage of Exceedances at Whatcom Creek						
Parameter	**2021**		**2022**		**2023**	
	#	**%**	**#**	**%**	**#**	**%**
Water Temp ^{0}C	4	33	4	31	3	20
Dissolved Oxygen mg/L	3	30	2	15	6	46
pH	0	0	2	15	0	0
Turbidity uS/cm	0	0	1	8	1	7
E. coli cfu/100ml	3	25	2	15	1	8
Entero cfu/100ml	-	-	-	-	2	40
Color	1	8	0	0	5	36
Odor	1	8	0	0	0	0
Lead ppb	-	-	-	-	1	50
Sulfate ppm	-	-	-	-	2	100
Zinc ppm	-	-	-	-	1	50
Fluoride	-	-	-	-	1	50

PFAS Compound	Amount detected ppt
Total	0

Rating: Threat

4. Padden Creek:

Photo of Creek:	**Approximate drainage area:**
	

Number of Exceedances and Percentage of Exceedances at Padden Creek						
Parameter	**2021**		**2022**		**2023**	
	#	**%**	**#**	**%**	**#**	**%**
Water Temp ^0C	-	-	2	22	2	13
Dissolved Oxygen mg/L	-	-	3	33	3	23
E. coli cfu/100ml	-	-	0	0	3	23
Entero cfu/100ml	-	-	-	-	4	50
Color	-	-	4	44	13	87
Visual	-	-	2	22	3	20
Sulfate ppm	-	-	-	-	4	80

PFAS Compound	Amount detected ppt
PFPeA	1.8
PFHxA	2.6
PFHpA	1
PFOA	2.1
PFBS	2.6
PFOS	2.4
3:3 FTCA	1.1
Total	**13.6**

Rating: Watch

Table 4. Total PFAS detected - organized from highest to lowest.

Station	No. of PFAS compounds	Total PFAS ppt
Cedar	10	53.4
Olive	7	33.9
Bennett	7	31.0
C st	7	21.9
Squalicum at Cornwall	7	18.8
Padden	7	13.6
Squalicum at Roeder	6	12.8
Cornwall	6	11.9
Broadway	5	8.6
Little Squalicum	3	5.0
Whatcom	0	0

Conclusion

The third year results show that the water being discharged into Bellingham Bay consistently exceeds water quality standards set by Washington State. There were 167 exceedances (177 if the presumptive *E. coli* exceedances are included), which is very similar to the 177 exceedances detected in 2022. Based on this data, it does not appear that stormwater quality is improving. **Five of the 6 outfalls and 3 of the 4 creeks are rated as being a "threat" (two more than in 2022) - this means that the water coming from these outfalls and creeks is likely contributing to an already contaminated Bellingham Bay.** A "watch" rating means that this outfall or creek may be contributing to pollution but that some of the exceedances are likely natural and not a problem and/or the exceedances are not frequent or extreme. While much progress is being made to address legacy contamination in Bellingham Bay, the results from this monitoring work indicate that stormwater pollution could contribute another source of contamination to the Bay.

The following parameters had documented exceedances from highest to lowest (number of exceedances in parentheses): color (57), water temperature (30), visual (29), *E. coli* (25), *Enterococcus* (24), dissolved oxygen (18), odor (15), and turbidity (5). *Enterococcus* was only monitored for 4 months, whereas all these other parameters were monitored for 12 months which means this number could be underestimated. The 4 months it was monitored, however, tend to be the rainiest months which typically have higher bacteria counts. Bacteria exceedances, in general, went down between 2022 and 2023, but other exceedances increased to make the difference between the 2 years negligible. Over half of the exceedances are observational (color, odor, and visual) which can be subjective and caused by natural and benign sources such as natural tannins in the water. Bringing on community volunteers in the fall could also have affected these numbers. As a part of harmonizing the procedures across all 7 programs there was effort made to reduce the subjectivity of these observational parameters but this also increased the likelihood that they would be categorized as a 1 or more (see Appendix 2 and 3). These parameters are very valuable, however, because these reports can note certain pollutants that may not be picked up by the YSI or turbidity meter such as a fossil fuel sheen.

Chemical strip tests were run for 4 months and the most common chemicals found were sulfate (23) followed by zinc and fluoride (both 9), mercury (5), lead (4), nitrite (4), and nitrate (3).

C st outfall, once again, had the largest number of exceedances with 37 followed by Squalicum creek (29), Padden creek (24), Cedar outfall (17), Whatcom creek (16), Broadway outfall (13), Little Squalicum creek (14), Cornwall outfall (11), and Olive and Bennett (both with 9). The number of exceedances don't necessarily correlate with the rating the stations were given, however, see the short discussions below for each site discussed in order of exceedances (most to least).

C Street outfall (rated a "threat") continues to be one of the most problematic outfalls. It continues to have a chronic yellow hue, sulfur/ fossil fuel smell, fossil fuel sheen, *E. coli* exceedances, and the presence of a white microbial mat. The white microbial mat was DNA analyzed in 2022 and consists mostly of the 5 following species: *Methylomonas*, *Pseudomonas*, *Hydrogenophaga*, *Sulfitobacter*, *and Flavobacterium.* Research suggests that these bacteria species may be growing in response to polluted water, potentially sewage. *Pseudomonas* is a known human pathogen.

Additional tests show the frequent presence of various chemical pollutants at this outfall including: lead, nitrate and nitrite, sulfate, zinc, fluoride, and PFAS. Only Squalicum creek had more chemical pollution detections. C st outfall flows under a marine trades industrial site and the Central Waterfront toxic cleanup site and drains a heavily built out area of town. It is not known where the pollution is coming from because there are so many potential sources. Up-the-pipe sampling and additional lab analysis could help trace the origin of the pollution.

Squalicum creek (rated a "threat") also continues to struggle to meet water quality standards. It has a chronic yellow hue, is turbid on occasion, and usually has foam on its surface. It gets too hot and hypoxic (low dissolved oxygen) to support salmonids in the summer months. Additional tests show it had the most chemical pollution detections of any station including: lead, chlorine, nitrate and nitrite, sulfate, zinc, and PFAS. This creek faces a triple threat — it is fed from water that comes from industrial parks, agricultural lands, and heavily built out commercial and residential parcels. Conducting upstream sampling and further lab analysis would help determine the source of these pollutants so they can be curbed.

Padden creek (rated a "threat") had 24 exceedances. While most of them were due to an observed light yellow color which could be due to natural tannins, it also experiences high temperatures and low dissolved oxygen levels during the summer months which is unhealthy for salmonids. It also shows the presence of sulfate and PFAS; however, the data suggests that the creek does not suffer from as much chemical pollution as Squalicum creek.

Cedar outfall (rated a "threat") had the highest PFAS amount of all the stations (53.4 ppt) and chemical test strips show the frequent presence of mercury, sulfate, zinc, and fluoride. It had the same number of detections as C st, which was second only to Squalicum creek. Cedar outflow often has a yellow, brown hue and a strong sulfur smell. Stormwater is contributed mostly from residential and commercial areas, but the pipe also flows under the RG Haley toxic cleanup site. This area is scheduled to be cleaned up and converted into a public park (Salish Landing) in the next few years. Sampling may need to stop during construction; additional pre- and post-cleanup testing may help understand where the contaminants are coming from.

Broadway outfall (rated a "watch") drains mostly residential areas and has moderate pollution concerns and was given a "watch" rating. It has a chronic yellow hue and had infrequent detections of chlorine, nitrite, and PFAS. Currently, bacteria is not a major concern at this outfall. This outfall discharges into I & J waterway which is a toxic cleanup site.

Little Squalicum creek (rated a "watch") was not monitored for the entire year and its status post-restoration is still to be determined. There were 3 *E coli* and 3 *Enterococcus* exceedances in the 10 months that it was sampled, which suggest that bacteria may be an issue here; the creek receives water flowing from an off-leash dog park which is a likely source of bacteria. Tests also showed the presence of sulfate, zinc, and PFAS.

Whatcom creek (rated a "threat") gets too warm and hypoxic (low dissolved oxygen) to support salmonids during the summer months which is the main reason it is given the "threat" rating. Other pollutants found in Whatcom creek were lead, sulfate, zinc and fluoride — but it was the only station where PFAS was not detected. Whatcom creek is the biggest system (most flow) in our program and this amount of water can dilute pollution and make it harder to detect. It starts at Lake Whatcom and flows through industrial parks, commercial and residential areas, as well as some public parks and restored riparian areas.

Cornwall outfall (rated a "threat") suffers from warm and hypoxic flows and like its neighbor Cedar outfall, it also has frequent presence of numerous chemical pollutants: mercury, sulfate, zinc, fluoride, and PFAS. There were 3 detections of mercury in the 4 months of sampling, which is concerning. Cornwall outfall drains a small section of the commercial area around Cornwall Ave and flows adjacent to the Georgia-Pacific toxic cleanup site where mercury was used in industrial processes. Follow-up lab sampling for chemical contaminants could be helpful in determining the magnitude of the pollution coming out of this pipe.

Olive outfall (rated a "threat") has warm water with relatively frequent bacteria exceedances. Tests detected the presence of mercury and sulfate and this site had the second highest PFAS detection (33.0 ppt) of any station. Its close proximity to a small pocket beach at the northern end of Boulevard Park where people and dogs swim regularly elevates the health risk posed by the water coming out of this pipe. Additional studies would help determine the sources and extent of pollution coming from this pipe.

Bennett outfall (rated a "threat") has warm temperatures and frequent bacteria exceedances. Sulfate was detected twice and the PFAS detection (31.0 ppt) was the 3rd highest of all the sites. The bacteria levels were not as high as in 2022 but were similar to levels in 2021. Some of the bacteria samples this year were 3 to 15x the threshold limit. Bennett outfall drains Sehome hill from the Lowell neighborhood and discharges in front of the Chrysalis hotel at a popular beach. This is also in close proximity to Taylor dock where people swim all times of the year. Because of the frequent bacteria exceedances with large spikes and the real potential for exposure, this area has been identified as a place to add to the state wide BEACH (Beach Environmental Assessment, communication & Health) monitoring program. The BEACH program monitors the safety of saltwater swimming beaches from Memorial day to Labor Day and is co-lead by the Department of Ecology and the State Department of Health.

Discussion

Year 3 of this stormwater monitoring program brought significant changes — joining forces with 6 other programs to form the Salish Sea Stormwater Monitoring Program, recruiting and training volunteers to take over monitoring, the harmonizing of procedures and data sheets, the introduction of a turbidity meter and *Enterococcus* sampling, and a fall flush PFAS sampling event.

The Health Department and the Department of Ecology used the data from this project to establish an additional sampling site to their BEACH program in front of Bennett outfall. Three water samples will be taken regularly between Memorial Day and Labor Day and sent to a lab to be processed for bacteria. In addition, our team will take water samples from the same place and same time as the BEACH samples and will run R cards so a comparison between lab and R card analyses can be done.

The Department of Ecology issues cities a NPDES (National Pollution Discharge Elimination System) Stormwater Permit as a means to manage stormwater pollution. Detailed Stormwater Management Manuals are provided to give permittees guidance on how to minimize and avoid stormwater pollution. These permits run on the presumptive approach that if a city follows all of the recommended and required stormwater management practices in the manual then all of the water quality standards will be met. **Cities are not required to monitor their stormwater, however, so there is no way of really knowing if the stormwater is polluted. The results from Bellingham's stormwater monitoring program, in fact, demonstrate that the stormwater being discharged into Bellingham Bay is polluted.**

The stormwater permit also has specific language of how a permittee is to detect and eliminate illicit discharges (ie. pollution). When pollution is reported, the permit holder must identify the source of the pollution through field screening, inspections, monitoring, and other source tracking as necessary such as the use of tracing dye and smoke. The stormwater team from the City of Bellingham has indicated that some follow up work has been done on some of our pollution reports for this program, for example, after a report of 7,000 CFU of bacteria was recorded at Bennett outfall (over 20x the exceedance level) they replied that a staff member was going to try "to see if there is any evidence of sewer spills or similar in the drainage basin." They did not indicate that a follow up study would be done to attempt to trace the source of the bacteria, however. One of our last communications with the stormwater team was in November, 2023 when we reported exceedances at nearly every monitoring site. The city expressed their concern but did not indicate that they would do a follow up analysis but instead said they "do not have the resources to do detailed source tracing for all pollutants found in stormwater." Detailed source tracing for ***all*** pollutants found in stormwater would be a large endeavor and quite expensive, we are requesting source tracing *only* for the pollutants that we are detecting during our sampling efforts, mainly *E. coli*. Other cities in this program have utilized the data from these stormwater monitoring programs to find illicit connections between sewer and storm drains and were able to stop the bacteria contamination.

1n 2024, monitoring will continue at all 10 sites in Bellingham and will primarily be carried out by 4 teams of volunteers. More effort will be made to understand the health and environmental consequences of the pollution that is being detected by this monitoring program as well as identifying the possible sources of contamination with the ultimate goal of stopping the pollution. This will likely involve working with stormwater permittees and holding them accountable for permit compliance. Billions of dollars are being spent to clean up Bellingham Bay and an important part of recovery is to ensure that it is not being contaminated by chronic stormwater pollution.

Acknowledgments

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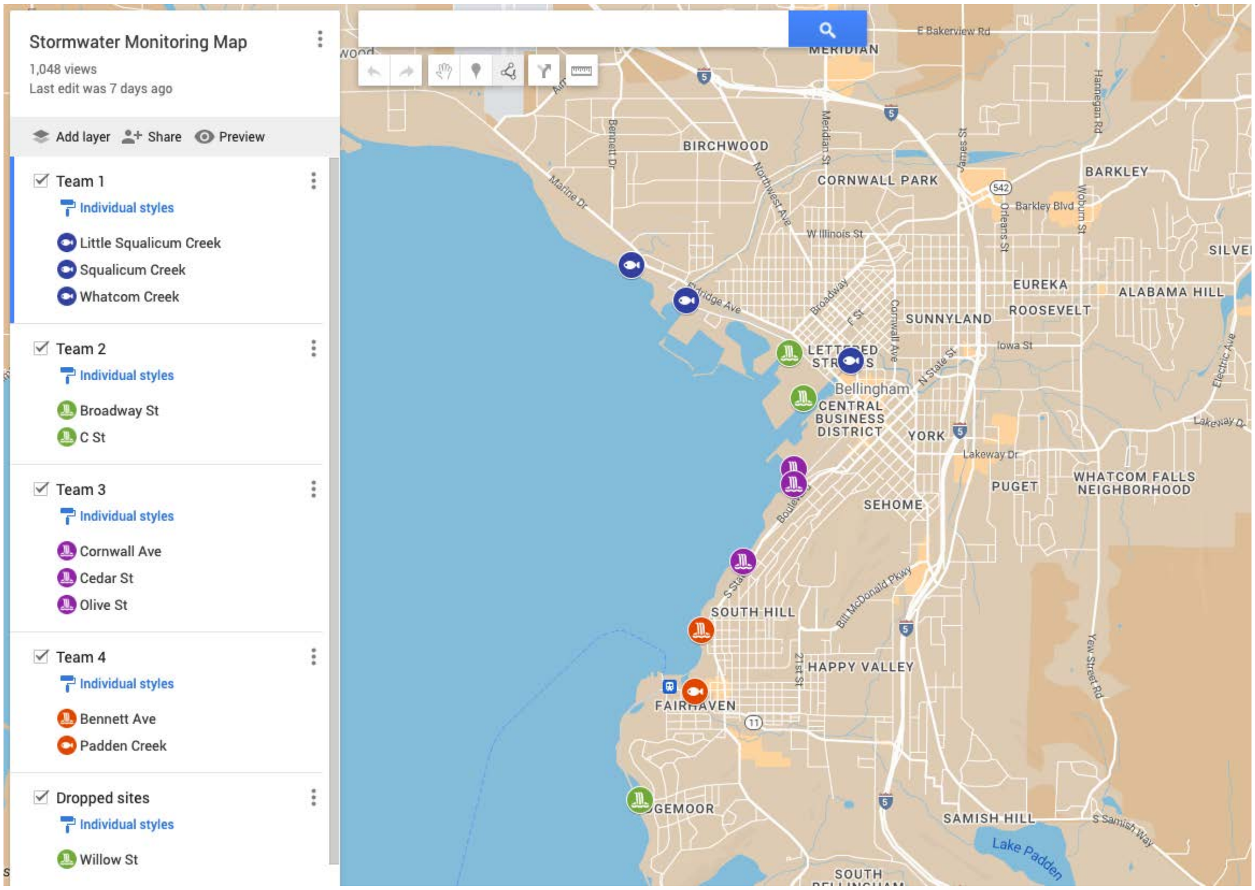
Appendix 1

Map of monitoring sites:



For more detailed information visit the interactive map at:
https://www.google.com/maps/d/edit?mid=1amVsqVcAC_aB7gOTbqloF_5NFblasnAq&usp=sharing

Appendix 2

Stormwater Monitoring Field Procedures

Salish Sea STORMWATER MONITORING

Background

The Washington Department of Ecology and Puget Sound Partnership acknowledge stormwater is the largest contributing factor to pollution in Puget Sound. Monitoring stormwater draining into Puget Sound is inadequate, as readily acknowledged by stormwater managers. Communities lack funding and capacity to monitor and characterize their stormwater systems. Southern Resident Killer Whales (SRKW) as top-tier predators in the Puget Sound food web experience serious consequences from pollution and necropsies of dead whales have revealed high levels of toxic pollutants.

This project will build capacity by using community science volunteers to help city/county/tribal stormwater managers to identify stormwater pollution sources, focus mitigation and/or corrective actions, and improve water and habitat quality for SRKWs and other marine inhabitants of the Salish Sea.

Goals

- Monitor pollution levels in stormwater outfalls and streams discharging into the Salish Sea
- Provide city and state regulators high quality data on stormwater pollution levels to assist them in conducting investigations to identify and eliminate illicit discharges
- Improve the water quality of the Salish Sea and tributary streams for all the wildlife that depend on it

Before You Head Out

- Print out or get Stormwater Monitoring Worksheets from https://stormwater-salishsea.org/
- Fill out top of the YSI/Turbidity Field Worksheet & the Bacteria Lab Worksheet
- Assemble Equipment:
    - Map of Sites
    - Clipboard
    - Worksheets - Field, Lab & Obs.
    - Field Notebook - reference docs
    - Plastic folder
    - Pen/pencil
    - Sharpie
    - Hand sanitizer
    - Plastic gloves
    - YSI -Turn on before packing!
    - Sampling Buckets
    - Distilled water
    - Phone/camera
    - Turbidity meter, empty vials, calibration vials & cloth
    - Sampling containers for bacteria
    - Cooler & ice/icepack
- Determine the tide height at start of sampling: www.tidesandcurrents.noaa.gov. Most sites require a low tide, less than +2', to sample.
- Determine rainfall for past 24 hrs (in): Record the rainfall for the 24 hours just preceding start of sampling. For best source of rainfall data for your city visit https://stormwater-salishsea.org/

In the Field

1. **As you are leaving to sample, turn on the YSI meter** by pressing and holding the ON/OFF button. At the first monitoring location, (turn meter on if you forgot) remove the gray vinyl sleeve and place meter in the shade while you get set up. You can leave the instrument on in between outfalls.

2. **Arrival Time:** Record the time when you begin sampling. Use your smartphone.

3. **Flow:** Note the flow of water in the creek or coming out of the pipe and record as N, T, M or H. Indicate if flow is greater than expected given the last 24 hours of rain. Do not take a sample or monitor in stagnant water.

Flow Rate	Stormwater Outfall	Creek
N = none	no flow/stagnant pooled water	creek bed is dry
T = trickle	fills 16 oz. cup in 2 minutes	lots of exposed rocks/sediment
M = moderate	between trickle and high	between trickle and high
H = high	fills 16 oz. cup in 5 seconds	flow close to high water mark

4. **Air Temp:** While the YSI meter is out of the sun, read air temperature and record on the worksheet. If it is windy, protect probe from the wind.

5. Collect water to sample: Be sure hands are clean or wear nitrile gloves to avoid sample contamination and protect yourself from potential contaminants. Collect sample water from the outfall or creek by rinsing the plastic bucket 3 times with the water to be sampled and then collecting a 4th sample to measure. Avoid collecting sediment with the water sample, avoid touching the water or inside of the bucket. If you cannot directly sample from the creek or outfall for bacteria and turbidity measurements, you may want to collect 2 buckets.

6. Collect samples for *E. coli and Enterococcus* bacteria:
    a. Collect the water sample from flowing water at the site (preferred method) using a sterile bottle, rinse the bottle and cap 3 times with sample water before collecting the sample. If the flow is too low, rinse and collect the sample from the sampling bucket that has been rinsed 3 times prior. Do not touch or contaminate the inside of the bottle or cap.
    b. Tightly screw the lid back on the sample bottle. Record the bottle letter on the worksheet.
    c. Keep the samples at 4°C (40°F) by placing them in an ice-filled cooler. Within 6 hours of sampling either begin culture procedures or place in a refrigerator.

7. **Turbidity** (ntu):
    a. Turn on the AMSTAT Turbidity Meter by quickly pressing POWER - top center button.
    b. Rinse the sample vial 3 times with stormwater directly from the outfall or creek (preferred method) or pour water from a sample bucket that was used to sample for bacteria. If using water from the sample bucket - collect turbidity sample immediately after collecting sample so heavy particles don't have time to settle out.
    c. Collect a 4th vial to be sampled.
    d. Dry and clean the vial with a soft cloth, shammy, or Kimwipe to remove any water

droplets, dirt and fingerprints from the vial. These may result in an inaccurate measurement.

e. GENTLY (to avoid introducing air bubbles) invert the vial three times before testing.
f. Place the vial in the AMTAST meter lining up the black dot on the lid with the gray arrow on the meter.
g. Quick press READ button - bottom center button. Turbidity number appears within 10-15 seconds.

Troubleshooting: If the turbidity meter readings seem unusual

- Remove sample vial, gently invert three times and read again.
- Check meter performance by reading calibration vials.

h. Record measurement on the worksheet.
i. Remove vial and discard sample water, rinse with distilled water.

8. **Water Temperature** (T) C°, **Dissolved Oxygen** (DO) mg/L, **Specific Conductivity** (SPC) µS/cm, **Salinity** (ppt), and **pH:**
    a. Measure using the YSI Meter.
    b. Dip the probe in the water sample and stir gently for 15 seconds. Parameters should be measured as soon as possible after the sample has stabilized as conditions in the bucket will change quickly.
    c. DO will take the longest to stabilize. Swirl the probe quickly, but slow enough to not spill the sample. If you are swirling too fast, DO will keep increasing. If you are swirling too slow, DO will keep decreasing. When DO is both increasing and decreasing slightly with a random pattern, it is time to take the reading.

Troubleshooting: If the DO probe provides unusual measurements;

- abnormally high values greater than 20 mg/l,
- negative numbers,
- never stabilizes,
- or values swing up and down no matter if you stir or not,
- then likely the membrane in the yellow cap is perforated or split.
- Disregard the DO values for the rest of the survey. The yellow cap will require replacement and we have plenty on hand.
- Email the person who calibrates the instrument when you return the instrument. Report that the DO cap membrane is possibly perforated or split.

d. Record the values shown on the meter on the worksheet.
e. Replace the gray vinyl sleeve.

9. Observations of the outfall or creek, the sample and immediate downstream area:
    a. **Color**: Assess color qualitatively using visual observations of how severely a sample is discolored. Observations included brown, reddish brown, light green etc… Record the color seen followed by a 1 to 3 scale. Ex: Brown, 3. See below.
    b. **Odor**: Assess odor by describing the intensity or severity of odor. Observations may include sulfur, fossil fuel, sewer, perfume etc. Record 0 or the odor/smell followed by a 1 to 3 scale. Ex: Rotten eggs 2. See below.

c. **Visual Indicators**: Document the visual observations by describing objects that are on the surface of the water. Observations include sheen, floaters, foam etc... Record 0 or the visual followed by a 1 to 3 scale. Ex: Sheen 1. Take a photo to document. See below. NOTE: If the situation is complex with multiple odors, color and other visuals, fill out a detailed Color, Odor & Visual Indicators Worksheet for the outfall.

Color Severity Scale		Odor Severity Scale		Visual Indicators Scale	
0	None	0	None	0	None
1	Faint color in sample	1	Faint odor	1	Few/slight
2	Color clearly visible in sample	2	Odor easily detected	2	Moderate
3	Color clearly visible in outfall flow or creek	3	Odor noticeable from a distance	3	Excessive/severe

10. At any time, if you note a significant source of pollution (ex: large oil sheen, rushing water when it hasn't rained, very strong color or odor) immediately call one of the contacts numbers listed below in the section "Contacts to Report Pollution".

11. Pack up equipment and clipboard and proceed to the next site, repeat steps 1-10.

12. Turn off the YSI meter after the last sampling site.

Back at the Lab

1. Create a digital copy of your worksheets:
   a. Use your smartphone to photograph the worksheet into a HEIC or jpg file or
   b. Use any other method that generates a clear, readable pdf, jpg, or HEIC file.

2. Email to woodc@umich.edu. Chris Wood will add your data to our stormwater database.

3. Put your worksheet in the appropriate file.

4. Clean & Store Equipment:
   a. Wipe YSI meter down with Clorox sanitizing wipes.
   b. Wipe YSI cable down with Clorox wipes.
   c. Remove gray vinyl probe cover and set it in white tub in an upside-down position.
   d. Knock out yellow sponge and leave in the tub, also.
   e. Place YSI probe into 1 qt storage container filled with pink pH 4 solution, in the tub.
   f. Wash sample cup and turbidity vials with a dilute mixture of DAWN dish soap and water. Place in tub to air dry.

Reporting Pollution

- Department of Ecology Spills Response (800) 258-5990
- National Spills Response (800) 424-8802
- Department of Ecology NW Regional office, Bellingham: (360) 255-4400
- Stormwater Hotlines:
  - Anacortes (360) 293-1921
  - Bellingham (360) 778-7979
  - Edmonds (425) 771-0235
  - Everett (425) 257-8821
  - Mukilteo (425) 263-8088
  - Oak Harbor (360) 279-4764
  - Shoreline (206) 801-2700

Parameters - What they Indicate

Outflow: Flow in an outfall during dry weather is an indicator that a water source other than stormwater is flowing through the storm drainage system. It could be natural groundwater flow but could also be sanitary sewer cross-connection, potable water (swimming pool, hydrant flushing), or illegal dumping.

Color: The color of water is influenced by the presence or absence of substances such as metallic salts, organic matter, dissolved or suspended materials. Color can indicate when stormwater has been contaminated by an illicit discharge or illicit connection, but not all illicit discharges will have a color.

Odor: Odor should be assessed qualitatively in the field using your nose to determine if a water sample has a distinct smell. Odor observations are subjective and may include descriptions such as a petroleum, sewage, or chemical odor.

Visual Indicators: Visual indicators other than color, odor, and flow can often indicate when stormwater has been contaminated by an illicit discharge or illicit connection; however, not all illicit discharges will have visual indicators. Visual indicators are assessed qualitatively by field staff using simple visual observations. Ex: abnormal vegetation, algae/bacteria/fungus, deposits/staining, fish kills, floatable, surface film/sum/sheen, or trash/debris.

Water Temperature (T) °C: Temperature extremes can threaten the health and survival of fish and other aquatic species in many life stages including embryonic development, juvenile growth, and adult migration. Water temperature can be useful in identifying contamination by sanitary wastewater or industrial cooling water. Household and commercial sewage produces heat due to microbial activity during anaerobic decomposition, while industrial cooling water is heated as it is circulated through heat exchangers. Water temperature measurements are typically the most useful for IDDE when indicator sampling is being conducted during cold weather and temperature differences can be significant.

Dissolved Oxygen (DO) mg/L*:* DO is an important parameter for salmonids and other aquatic organisms. Low dissolved oxygen levels can be harmful to larval life stages and respiration of juveniles and adults. DO depends on local hydraulic conditions affecting the oxygenation of the discharge. For this reason, DO is not a widely useful indicator for illicit discharges.

Specific Conductivity (SPC) µS/cm*:* Specific conductivity, also referred to as specific conductance, is a measure of how well water can conduct an electrical current based on ionic activity and content. Specific conductivity is an indicator of dissolved solids from potential pollutant sources such as sewage and wash water, and can help distinguish groundwater from illicit discharges and identify commercial/ industrial liquid waste if used in combination with another parameter such as Hardness, Turbidity, or Detergents/Surfactants. Specific conductivity can also be used in combination with caffeine or pharmaceuticals (see Other Indicators) to indicate sanitary wastewater.

Salinity (ppt)*:* This is the saltiness or dissolved inorganic salt content of water. The Pacific Ocean has an average salinity of 34 parts per thousand (ppt) compared to 29 ppt in Puget Sound. Measuring salinity will indicate if there is saltwater intrusion in the outfall or creek which will affect conductivity (make it higher).

pH*:* pH measures the hydrogen ion activity on a scale from 1 to 14. Water with a pH below 7.0 is acidic and water with a pH above 7.0 is alkaline or basic. pH values that are lower than 6.5 or higher than 8.5 may be harmful to fish and other aquatic organisms. A low pH can cause heavy metals to leach out of stream sediments, resulting in an increase in dissolved metals concentrations. A high pH can produce a toxic environment, in which ammonia becomes more poisonous to aquatic organisms.

Turbidity (ntu): Turbidity is a measure of how transparent or clear water is based on the amount of sediment or suspended particulates. Large amounts of suspended material can affect fish growth and survival by impairing their vision, gill function, and affecting egg and larval development. Higher turbidity can also increase temperature and thereby decrease dissolved oxygen concentrations in water bodies, affecting the growth of both aquatic animals and plants. High turbidity in water can be attributed to many different sources including soil erosion, construction activities, sanitary wastewater, excessive algal growth, or industrial processes.

***E. coli and Enterococci* Bacteria (cfu/100 ml)**: These bacteria indicate the presence of fecal contamination by warm-blooded animals. *E. coli is* typically used as an indication of fecal contamination of stormwater and fresh water systems while *Entero* is used as an indication of fecal contamination in marine waters. A relatively elevated test result for fecal coliform bacteria may indicate an illicit discharge or illicit connection associated with sewage or a failing septic system. However, it may also indicate waste related to large domestic animals (such as cows, llamas, etc.), pets, or wild animals.

References

- WA Stormwater Center: https://www.wastormwatercenter.org/
- Stormwater Action Monitoring (SAM) Program
- IC-ID Field Screening and Source Tracing Manual May 2020
- COB Surface and Stormwater and Comprehensive Plan 2020

Due next week

SEQUENCE & CHECKLIST
Stormwater YSI & Turbidity Monitoring Procedure

Salish Sea STORMWATER MONITORING

First of the month

- Check daytime low tide dates for your town.
- Select your day & reserve equipment

Before you head out

- Print out Stormwater Monitoring Worksheets: https://stormwater-salishsea.org
- Fill out top of YSI/T Field Worksheet & Bacteria Lab Worksheet if you are gathering water samples.
- Determine rainfall for the past 24 hours: www.weather.gov. Enter your town in the box, select the closest weather station, hit enter.
- From options on the right, select 3-day history. Find your start time in the table.
- Assemble equipment and instruments.
- Turn on your YSI meter.

In the field, at each outfall

- Record your arrival time.
- Record the Flow & Air Temp
- **Bacteria**: Collect bacteria samples. Rinse container 3x & keep 4th fill.
- **Turbidity:** Rinse vial 3x & keep 4th fill.
- Wipe vial with microfiber towel to remove water, debris, & finger prints.
- Invert vial 3x gently & insert into meter. Record data on worksheet. If meter reading is 00.0, invert vial 3x gently again & re-read.
- **Water Quality Test Strips**: Follow procedure on worksheet.
- **YSI Meter:** Dip probe in water sample & record data on worksheet.
- **DO** will take longest. Swirl/stir probe quickly, but slow enough not to spill sample. When DO increases or decreases slightly in a random pattern record the value.
- **Observations of outfall or creek.** Record color, odor & visual indicators.
- Leave YSI meter on between sites.

Back at the lab

- Complete worksheet. Include end time.
- Photograph worksheet with smartphone & send to **woodc@umich.edu**
- Rinse out sample cup & vial of any sediment or debris.
- Turn off YSI meter & wipe instrument with clorox wipes. Remove grey vinyl probe cover and place probe in pink storage solution.

1 2024-01-01 ver2.4

Equipment Checklist

- Map of Sites
- Clipboard
- Data Worksheets
- Field notebook
- Pen/pencil/Sharpee
- Hand sanitizer
- Plastic gloves
- YSI instrument – turn on before packing in backpack
- Sampling cup or bucket
- Phone
- Turbidity meter, vial, and cloth
- Bacteria sampling containers
- Cooler and icepack for bacteria bottles when full.
- Backpack

Appendix 3

Bacteria Processing Procedure

Salish Sea STORMWATER MONITORING

Pre-Incubation Sample Processing

Part 1: Initial Workstation Preps

1 Sterilize tap water that will be used for sterile water sample in the processing:

2 Obtain 1/2 cup to 3/4 cup of tap water in microwaveable container. Either a plastic sample bottle or the 100ml beaker will work

3 Microwave the tap water at 100% power, for 60 seconds to sterilize

4 Let the sterile water cool, approximately 5 minutes. NOTE: Sterile water can last up to 72 hours, if tightly capped.

5 Turn on Incubator - set to 37 degrees Celsius (97 degrees Fahrenheit)

6 Sterilize workstation: Spray with isopropyl alcohol

7 Gather items needed to perform analysis of water samples (per number of samples to be done)

8 Wash and sanitize hands, using soap & water or hand sanitizer.

Part 2: Prep R-Card and Bacteria Worksheet

1 Label R-Card (one for each sample)

- A. When using 2-sided R-card, label both sides of the R-Card
- B. Label includes:
    - I. Current date
    - II. Field site ID
    - III. Sample Bottle letter
- C. For duplicate sample (positive control), add "Dup"
- D. For sterilized water sample (negative control), add "NC"

2 Fill out Bacteria Worksheet

- A. Name(s) of Lab Tech(s)
- B. Date of processing (yyyy-mm-dd)
- C. Start time of processing (hh:mm)

Part 3: Prepare Stormwater Sample

Note: If processing 2nd side of R-Card, you can use the same graduated cylinder for the second sample (same outfall)

1 Using a sterile, graduated cylinder, placed on the workstation area

- A. Invert stormwater sample bottle (once)
- B. Pour stormwater sample into graduated cylinder to the 100 ml line

Part 4: Prepare Filtering Device

1 Using the bottom part (blue top) of the filtering device,

- A. Place the white, paper pad on the top

2 Apply a thin film of petroleum jelly to orange, rubber O ring on bottom of filtering device – (ONLY before first sample – does not need to be done for each sample)

Part 5: Prepare Two-inch Filter Membrane

1 Note: always use sterilized tweezers to transfer filter membrane. Please do not use your hands. This will prevent cross-contamination of the samples.

2 Flame sterilize the tweezers:

- B. Votive candle method:
    - I. Light the votive candle with a lighter/matches
    - II. Dip tweezers in the vial of isopropyl alcohol
    - III. Hold the tweezer tips over the flame to ignite the isopropyl alcohol
    - IV. As soon as the tweezer "flames" move slightly from the candle and let "flame" until it goes out (sterilization technique referred to as "flaming")
    - V. Votive candle can be kept lit during processing. Please set it to the side – away from the alcohol dipping vial
    - VI. This method can produce a build-up of "soot" on the tweezers. If you need to clean the tweezers wipe with a cloth prior to each flaming.
    - VII. Do not wipe the tweezers after flaming – it will contaminate the tweezers possibly burn yourself.
- C. Bunsen burner method:
    - I. Light the Bunsen burner with a lighter/ matches
    - II. Dip tweezers in the vial of isopropyl alcohol
    - III. Hold the tweezer tips over the flame for 5 seconds (sterilization technique referred to as "flaming")
    - IV. Extinguish the Bunsen burner using foil cap or candle snuffer – do NOT blow the flame out (prevents contamination on the work surface)

3 Place 2 inch filter membrane on filtering device.

- A. Open the pouch with 2" filter membrane (use the 2" white filter membrane, not the blue paper)
- B. With the sterile tweezers, remove the 2" white filter membrane and place the 2" white filter membrane on the filtering device (on top of the

white pad) and grid-side up.

Part 6: Pull Stormwater Sample through the Filtering Device

1 Reassemble the filtering device:

- A. Put the top of the filtering device onto the bottom of the filtering device
- B. Twist the top clockwise (just a bit) to make sure the bottom and top are seated properly.
- C. NOTE: Twisting the top can rip the filter membrane (where top ring touches membrane).

Part 7: Draw Stormwater Sample through the Filtering Device

1 Pour a small amount of the water sample from the graduated cylinder into the top of the filtering device. Check for leakage.

2 Using the vacuum hand pump, draw the water sample through the 2" white filter membrane

- A. Attach vacuum hand pump to the filtering device – attach tube to side outlet
- B. Using one hand on the top of the filtering device, squeeze the hand control (creates vacuum)
- C. Continue squeezing hand control until the sample is drained into the bottom of the filtering device.

Part 8: Place Filter Membrane with Sample on the R-Card

1 Position the R Card near the filtering device

2 Flame sterilize the tweezers (refer to Section 5.1 above)

3 Using the sterilized tweezers, transfer the 2" white filter membrane from the filtering device to the R-Card

4 NOTE: Position the 2" white filter membrane so that the vertical gridlines are straight

5 Add sterilized water to 2" white filter membrane (this helps activate the nutrients on the cover of the R-Card)

- A. Using the sterile, plastic pipette, squeeze the top bulb and draw up 1ml of sterile water (there is a line indicating 1ml on pipette)
- B. Dribble approximately 0.5 to 0.75 ml of sterile water onto the 2" white filter membrane
- C. Lower the cover of the R-Card
- D. NOTE: Check to make sure that the sterile water has covered the filter membrane.

6 Record on both R-Card and Bacteria Worksheet

- A. "Time In" (hh:mm)
- B. Volume Sampled (ml)

Part 9: Process second side of R-card

1 Repeat Parts 3, 4, and 5 for the second side of the R-Card.

Part 10: Incubation

1 Place R-Card into the incubator:

- A. R-Card should be placed flat in the incubator
- B. R-Cards can be placed on top of each other
- C. R-Cards should not be placed standing up in the incubator (prevents cross-contamination of the samples).

Part 11: Sterilize Equipment(before processing next stormwater sample)

1 After second side of R-Card is processed:

- A. Pour unused water sample into the container labeled Water Disposal
- B. Place used items in the UNSTERILE bin:
- C. If flame Bunsen burner or votive candle is lit, extinguish flame
- D. Sterilization of equipment – between stormwater samples:
  - I. Filtering device (top portion and lid):
    - a. disassemble the filtering device into separate pieces
    - b. wipe the inner surface and the underneath with a paper towel
    - c. wipe lid with paper towel
    - d. place top portion and lid in the microwave for 30 seconds
- E. Filtering device (bottom portion and paper pad):
  - I. Nothing is required
- F. Sterilize graduated cylinder: Microwave for 60 seconds.
- G. Plastic pipette:
  - I. Draw in a small (around 0.25 ml) of 70% isopropyl alcohol, then empty the pipette into container labeled WATER DISPOSAL
- H. Wash and sanitize hands, using soap & water or hand sanitizer.

Part 12: Process next outfall sample

1 Repeat Procedure Parts 1 through 10 for each stormwater sample

2 NOTE: For every batch of stormwater samples,

- A. add one (1) duplicate water sample – process the duplicate directly after the original sample (remember to sterilize TOP PORTION ONLY of the filtering device between each sample). This is the positive control.
- B. one sterile water sample. This is the negative control. Do this sample last.

Part 13: Cleanup workstation -end of processing

Note: Do not put the bottom portion of filtering device in microwave. This melts the plastic walls.

1 Sterilize the used equipment:

   A. graduated cylinders, sampling bottles (with caps off) – up to 8 items at a time

      I. Microwave items for 60 seconds

      II. Return the sterilized graduated cylinders (topside down) and sampling bottles (without caps) to the STERILE bin.

   B. top portion of filtering device–if two were used, sterilize both

      I. Microwave for 60 seconds

      II. Return the sterilized top portion of filtering device to the STERILE bin.

   C. bottom portion of filtering device (end of each month):

      I. Squirt isopropyl alcohol into side vent of device

      II. Swirl around

      III. Empty contents into container labeled WATER DISPOSAL

   D. paper pad (used on bottom of filtering device) does not need to be cleaned. The pad can be changed when it has become very brown and dirty.

2 Dispose of the unused sample water from the container labeled WATER DISPOSAL

3 Return all items to their proper place

PLEASE NOTE: Bottom portion of filtering device should be placed in the UNSTERILE bin between monthly cleanings

4 Sterilize workstation: Spray with isopropyl alcohol

5 Wash and sanitize hands, using soap & water or hand sanitizer.

Part 14: Update Bacteria Worksheet

1 Fill in LAB PROCESSING: End time of processing (hh:mm).

Post-Incubation Sample Processing

NOTE: Processing will occur after approximately a 24-hour incubation period for all R-Cards

Part 1: Update Bacteria Worksheet

1 Fill in COLONY COUNTING & SCANNING:

   A. Name(s) of Lab Tech(s)

   B. Date of processing (yyyy-mm-dd)

   C. Incubator Time Out (hh:mm)

   D. Start time of counting and scanning (hh:mm)

Part 2: Remove R-Card from Incubator

1 Turn off Incubator and Remove R-Card from incubator

NOTE: do not lift the plastic sheet on the R-Card once it is taken out of the incubator. **The R-Card has growing E.coli colonies on it and is to be considered a Bio-Hazard.**

Part 3: Count Colony Forming Units (CFUs) on the incubated R-Card

1 For each R-Card side

   A. Count all the green dots - If you doubt it, don't count it.

   B. Record CFU count (upper right-hand corner of R-Card, using Sharpie)

   C. If there are too many dots, Record as TNTC (too numerous to count)

   D. If sample was less than 100ml, adjust the CFU count accordingly

   E. Add 'CFU' after your count number. IE., 66 CFU

Part 4: Update Bacteria Worksheet

1 Fill in COLONY COUNTING & SCANNING:

   A. E.coli (number of CFUs/100ml)

   B. Enterococcus (number of CFUs/100 ml)

Part 5: Document Bacteria Worksheet and R-Cards

There are detailed instructions to use Photo Box to document both the Bacteria Worksheet and R-Cards.

Please see Salish Sea Stormwater Monitoring website for these instructions:

https://stormwater-salishsea.org/docs/Procedures/PhotoBox_Procedure.pdf

Part 6: Safe Disposal of the R-Cards

1 Place all R-Cards in a plastic baggie

2 Using isopropyl alcohol

   A. Squirt, approximately 1ml into the plastic baggie and seal the plastic baggie

   B. Swirl the liquid around in the plastic baggie to ensure that all R-Cards are covered (this neutralizes the E.coli bacterial colonies)

   C. Dispose of the plastic baggie in the trash.

Appendix: Revision history

03.01.2023

1 Revised Outfall Sampling (Part 1; #4) – requirement for 2nd duplicate sample

2 Revised Outfall Sampling -- Added explicit expected delivery time of 6 hours

3 Revised Sample Processing (Part 3, Section 3b – Votive candle method) – added caution for soot build-up

4 Revised Sample Processing (Part 5, Section 2b – Votive candle method) – added caution for soot build-up

07.21.2023

1 Revised to include procedures for 2-sided R-Cards

2 Revised to make parts of the procedures clearer

3 Removed second detailed instructions for "flaming" tweezers

4 Removed lighter method for flaming

5 Removed instructions for documentation of R-Cards and Bacteria Worksheet – provided

6 link to new procedure.

Appendix 4

Stormwater Monitoring Worksheet - YSI/Turbidity/Visual

Salish Sea STORMWATER MONITORING

City		Date	

Investigators	Start Time	End Time

Tide Height (+/- ft)		Tide Time (24 hr)		Past 24 hr Rainfall (in)	

Weather (circle): Sunny/Clear Partly Cloudy Overcast Rain (Light Moderate Heavy) Snow

Site Name/ID#						Outfall Threshold*	Creek Threshold**
Arrival Time (24hr)						------------------	------------------
Flow: N,T,M,H / > then expected	Y or N	Y or N	Y or N	Y or N	Y or N	unexpected high flow	------------------
Air Temp (°C)						------------------	------------------
Water T (°C)						> ambient air	> 16°C
DO (mg/l)						< 6 mg/l	< 8.0 mg/l
SPC (µS/cm)						> 500 µS/cm*	
Salinity (ppt)						> 0.5 = likely marine intrusion	
pH						< 5 or > 9	< 6.5 or > 8.5
Turbidity (ntu)						> 50 ntu	stream specific
Color (0-3)						any non-natural phenom (≥ 1)	
Odor (0-3)						any non-natural phenom (≥ 1)	
Visual (0-3)						any non-natural phenom (≥ 1)	
Bacteria Sample Bottle #/Letter						------------------------------------	

Notes: Include descriptions of color, odor and other visual indicators.
Questions: Write them here and we will get you an answer.

*Department of Ecology Illicit Connection and Illicit Discharge Field Screening and Source Tracing Guidance Manual, May 2020
**Salmonid Core Summer Habitat and Primary Contact

2023-10-20 ver2.3

Protocol Reminders

- **YSI meter – turn on before you leave to sample** and leave on between sites.
- **Flow -** do not monitor/sample stagnant/pooled water. There **must be an observable flow**.
- **Rinse all containers 3x each** with outfall/creek water and keep 4th fill to sample/monitor.
- **Collect samples directly from outfall or creek** for bacteria and turbidity, when possible.
- **DO** - swirl **YSI** probe quickly, but slow enough not to spill sample. When DO value increases or decreases slightly with a random pattern record the value.
- **Turbidity: wipe off vial** to remove water, debris & finger prints. **Gently invert 3x** before testing.

Guide to Filling Out Worksheet

- **Investigators:** list all who are present. This is how we track volunteer hours for grants.
- **Tide**: record tide at start of sampling, example - 0.25' @ 13:14
- **Past 24hr Rainfall:** from the start of sampling; use recommended website/app for your city.
- **Air Temp:** read on YSI meter while it is shaded and protected from the wind.
- **Flow:** record appropriate letter. If flow is greater than expected based on rainfall, circle Y.

Flow Rate	Stormwater Outfall	Creek
N = none	no flow/stagnant pooled water	creek bed is dry
T = trickle	fills 16 oz. cup in 2 minutes	lots of exposed rocks/sediment
M = moderate	between trickle and high	between trickle and high
H = high	fills 16 oz. cup in 5 seconds	flow close to high water mark

- **Color:** Observations may include brown, reddish brown, light green etc... Record the color seen followed by the 0-3 severity rating. Ex: Brown (3).
- **Odor:** Observations may include sulfur, fossil fuel, sewer, perfume... Record the odor smell followed by the 0-3 severity scale. Ex: Rotten Eggs (2).
- **Visual:** Observations may include sheen, floaters, foam etc... Record the visual followed by 0-3 severity scale document. Ex: Sheen (1).
- **Any condition rated >0**: photograph and describe in Notes.

Color Severity Scale		Odor Severity Scale		Visual Severity Scale	
0	None	0	None	0	None
1	Faint - faint color in sample	1	Faint - odor barely noticeable	1	Few/slight
2	Moderate - color clearly visible in sample	2	Moderate - odor easily detected	2	Moderate
3	Intense - color clearly visible in outfall flow or creek	3	Strong - noticeable several feet away	3	Excessive/severe

Back at the Lab

- Complete data sheet. Include completion time.
- Snap photo of worksheet with smartphone and send to **woodc@umich.edu**
- Rinse out sample cup and vial of any sediment or debris.
- Wipe down YSI instrument with Clorox wipes.
- Remove grey vinyl probe cover and place probe in pink storage solution.

For additional resources and instructional materials visit: https://stormwater-salishsea.org/

Appendix 5

Stormwater Monitoring Worksheet - Bacteria

Salish Sea STORMWATER MONITORING

Volunteer Names	Volunteer Hours Tracking			City
Sample Collection	Date	Start Time	End Time	
Lab Processing				
Colony Counting				

PROTOCOL REMINDERS

- **Rinse** bottles 3 times before collecting sample, leave small air space.
- **Store** in small cooler with ice packs if especially hot.
- **Deliver** to lab no later than 6 hrs after collection.
- **Volume Filtered**: 20 ml | **Incubate** for 24 hrs.
- ***E. coli* Threshold** for resampling: > 320 cfu/100 ml
- ***Entero* Thresholds** for resampling: Stormwater Outfalls > 500 cfu/100 ml; Freshwater (creeks) > 110 cfu/100 ml

Outfall Number	Bottle Letter	Sample Time 24hr	Incubator Time In 24hr	Incubator Time Out 24hr	Volume Filtered ml	*E. coli* Count	*E. coli* Multiplier	*E. coli* cfu/100ml	*Entero* Count	*Entero* Multiplier	*Entero* cfu/100ml	Comments
-DUP					20 ml		X 5			X 5		Duplicate (Positive Control)
					20 ml		X 5			X 5		
					20 ml		X 5			X 5		
					20 ml		X 5			X 5		
					20 ml		X 5			X 5		
					20 ml		X 5			X 5		
					20 ml		X 5			X 5		
					20 ml		X 5			X 5		
					20 ml		X 5			X 5		
Sterile Water					20 ml		X 5			X 5		(Negative Control)

Notes: Include observations of odor, color or other visual indicators of possible pollution.
Questions: Write them here and we will get you an answer.

2023-10-04 ver2.0

Appendix 6

Stormwater Monitoring Worksheet – Water Quality Test Strips

Salish Sea STORMWATER MONITORING

City			Date						Thresholds*	
Investigators										
Site Name/ID#										
Arrival Time 24hr									Outfall	Creek
Strip Parameters	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2		
pH									<5 or >9	
Hardness ppm										
Hydrogen Sulfide ppm										
Iron ppm										
Copper ppm									>0.025 ppm >0.1 ppm	
Lead ppb									>100 ppb	
Manganese ppm										
Total Chlorine ppm									>0.3 ppm	
Mercury ppm										
Nitrate ppm									>1 ppm	
Nitrite ppm									>1 ppm	
Sulfate ppm										
Zinc ppm										
Fluoride ppm									>0.3 ppm	19 ppm acute 11 ppm chronic
Sodium Chloride ppm										
Total Alkalinity ppm										

Procedures:

1. Rinse collection container (test tube or cup) 3X with stormwater/creek and keep 4th for testing.
2. When possible, avoid testing in same sample cup the YSI meter is placed in.
3. Insert strip into sample for **2 seconds,** shake off excess water & lay along bottle label.
4. **Read entire strip in < 1 minute** or else the air will discolor the test strip & skew readings.
5. Record value of the **closest** matching color for each parameter. Do not make-up a number.
6. Repeat steps 1-4 for a second test.
7. If using test tube, rinse with distilled water and wipe clean if needed before next site.

Notes & Questions:

*Department of Ecology Illicit Connection and Illicit Discharge Field Screening and Source Tracing Guidance Manual, May 2020

2023-10-23 ver2.1

All of the parameters tested by the strips are either an indicator of a pollution problem or are themselves toxic to humans and aquatic life depending on the concentrations present. In addition to anthropogenic sources, some of these parameters are also naturally occurring in the environment.

Parameter	Sources
Hydrogen Sulfide	Produced by non-pathogenic bacteria; a result of metal corrosion.
Iron	Possible by-product of paint, tires, or other metals; used in construction of stormwater pipes.
Copper	Asphalt sealcoating, pesticides or fungicides may contain this metal; a galvanic corrosion protectant for equipment (boats & tanks); may be used in pressure-treated wood.
Lead	Was a major problem when lead was an additive in gasoline.
Manganese	Found in mining waste, industrial waste, automobile parts and fluids; also naturally occurring in sediment and rocks.
Chlorine	Primarily associated with treated water supplies and industrial discharges.
Mercury	Results from burning coal, oil & natural gas, burning household trash; vehicles before 2003 had mercury switches, lights; also present naturally in the environment.
Nitrate & Nitrite	In fertilizers, failing septic systems, discharges from waste water treatment plants, pet waste, livestock and farm animals and industrial discharges.
Sulfate	In groundwater including mineral dissolution, atmospheric deposition and other sources (mining, fertilizer, etc.); gypsum is an important contributor.
Zinc	In galvanized metal roofing, gutters, metal fences, hydraulic fluid, asphalt sealcoating; may also be in paints, tires, pesticides, fungicides; biocide used for roof cleanings or boat coatings.
Fluoride	Utilized in industry applications in the production of semiconductors, fertilizers, high purity graphite, and nuclear applications.
Sodium Chloride	For deicing use on roadways; intrusion of salt water from natural sources.
Alkalinity	Ability of the water to neutralize acidic components which may be pollutants.
Chlorine + Fluoride + Bacteria	Together indicate that there may be an illegal sewer connection or someone pumping RV sewage into storm drain.
Copper + Lead + Zinc	Together these are being used as an indicator that the toxic tire compound 6PPD-Q may be present.

2023-10-23 ver2.1